ANKYLOSTOMIASIS AND ITS CONTROL IN NORTH NYASA.

Thesis submitted for the Degree of M.D.,

Glasgow University,

by

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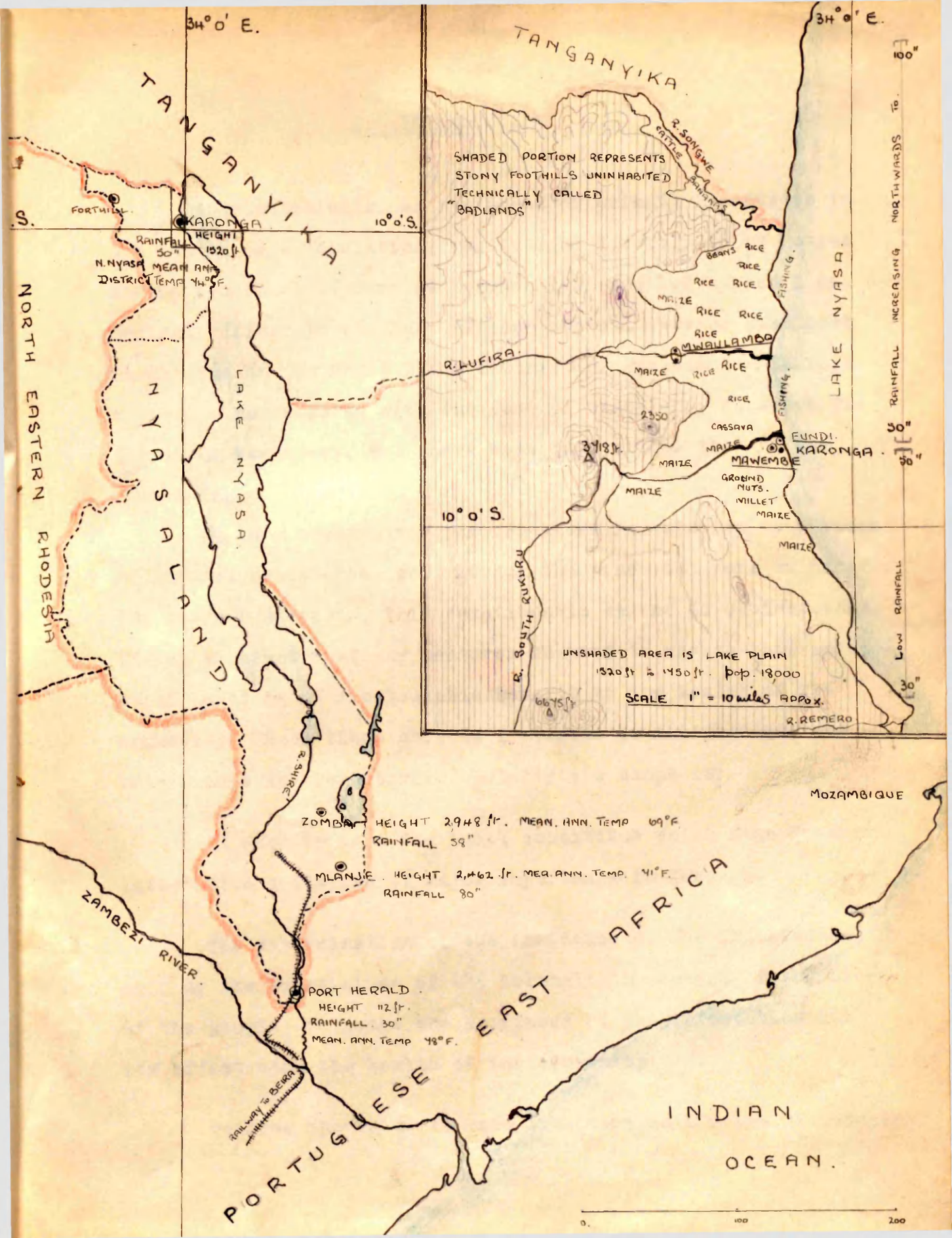

34° 0' E.
TANGANYIKA
10° 0' S.
FORTHILL.
KARONGA
HEIGHT 1520 ft
RAINFALL 50"
N. NYASA MEAN ANN. DISTRICT TEMP 74° F.
NORTH EASTERN RHODESIA
NYASALAND
LAKE NYASA.
R. SHIRE
ZOMBA HEIGHT 2,948 ft. MEAN. ANN. TEMP 69° F
RAINFALL 58"
MLANJE. HEIGHT 2,462 ft. MEA. ANN. TEMP. 41° F.
RAINFALL 80"
ZAMBEZI RIVER.
PORT HERALD.
HEIGHT 112 ft.
RAINFALL 30"
MEAN. ANN. TEMP 78° F.
RAILWAY TO BEIRA
PORTUGUESE EAST AFRICA
MOZAMBIQUE
INDIAN OCEAN.
SHADED PORTION REPRESENTS STONY FOOTHILLS UNINHABITED TECHNICALLY CALLED "BADLANDS"
R. SONGWE
CATTLE
BEANS
RICE
MAIZE
FISHING.
R. LUFIRA.
MWAILAMBO
2350
CASSAVA
FUNDI.
3418 ft.
MAWEMBE
GROUND NUTS.
MILLET
R. SOUTH RUKURU
UNSHADED AREA IS LAKE PLAIN
1520 ft to 1450 ft. pop. 18000
SCALE 1" = 10 miles APPROX.
6675 ft
R. REMERO
RAINFALL INCREASING NORTHWARDS TO 100"
LOW RAINFALL
50"
30"
0.
100
200

I. INTRODUCTION.

Ankylostomiasis, as a disease of primary importance in the health of a population, was brought forcibly to my notice during two tours of service between 1926 and 1931, when I was a medical officer in the East African Medical Service stationed at Karonga in the North Nyasa district of Nyasaland. In this district, as compared with the rest of Nyasaland, Hookworm Infestation was heavy, and there were indications that it was increasing.

It is a commonplace that Hookworm Infestation is a cause of lowered resistance, and, during the practical work of treating other conditions, this relationship became so obvious that it was apparent that any measures adopted to reduce this infestation would be of incalculable benefit to the health of the community. Upon these grounds I started investigations, and this thesis is the outcome. Briefly its scope is:-

An enquiry into the local conditions which make Hookworm infestation a disease of major importance in Karonga.

The determination of the incidence of the infestation, and, by the examination of the haemoglobin content of the blood of the people, to gauge the heaviness of the infestation and its effect upon the health of the community.

To show the value of mass treatment as a means of reducing the/

the disease to negligible proportions. By a careful watch on the haemoglobin value of the blood of the people, to determine when the infestation has increased sufficiently to merit another mass treatment campaign.

To propose the application of this simple method of dealing with Hookworm infestation to other districts where the problem of this disease exists.

In Appendix I to give the details of a mass treatment campaign in which a death occurred from poisoning by Carbon Tetrachloride in an alcoholic subject.

In Appendix II to give a note on the clinical diagnosis of Hookworm Disease with special reference to an early and a late sign.

II. A SHORT SUMMARY OF THE HISTORY OF ANKYLOSTOMIASIS.

Ankylostomiasis appears to have been known to the Ancients. There is some doubt if the Egyptians recognised it, but certainly Hippocrates described a disease which caused geophagy, brought on intestinal troubles, and gave the sufferers a colour not unlike jaundice. In classical times, the striking pallor of miners was mentioned by some writers, and much later in the seventeenth and eighteenth centuries various workers described the disease. It was not until 1838 that the actual worm was found and described by Dubini, and, in 1854, Greisinger mentioned this worm as the cause of Egyptian Chlorosis. Grassi and his two co-workers in 1877 showed that the disease could be diagnosed by the presence of Hookworm ova in the stools, and the St. Gothard Tunnel epidemic in 1880 focussed the attention of the world on this new disease. Looss, in 1898, completed our knowledge of the life history of the worm by his demonstration of the passage of infective larvae via the skin, lymphatics, blood vessels, heart, lungs, trachea, and oesophagus to the duodenum. Ankylostoma duodenale and Necator americanus were differentiated by Styles in 1902.(1)(2)(3).

The history since then has largely been the attempt of the American workers to develop methods of controlling the disease. 1909 marked their entry into the field, and, financed by the Rockefeller Foundation, teams of medical men have been attacking the problem in different countries. The activities of this/

this Foundation in 1927 on Hookworm control extended to nineteen different stations throughout the world. Since the War, the use of ova concentration methods associated with the names of Lane and Stoll have made diagnosis extremely accurate and the introduction by Hall of Carbon Tetrachloride (CCl_4) in 1921, and Tetrachlorethylene (C_2Cl_4) in 1926 has put treatment on a firm basis.

Tropical Africa has not shared in the activities of the Rockefeller Foundation on Hookworm control, and, even yet, very little is known about the state of the population with regard to this disease. Trypanosomiasis and its allied subject Tse-tse fly control have been the glaring problems of Africa and consequently investigations into Ankylostomiasis have suffered. In Nyasaland, nothing definite was known other than the fact that the disease existed, until 1912, when a report was made by Stannus[4] and sent to the Secretary of State for the Colonies disclosing "a serious state of affairs." The rate of incidence was estimated at 40 per cent, but 85 per cent of those harbouring worms were classed as lightly infested; so lightly infested indeed, as to merit the name "carriers."

III. AN INVESTIGATION INTO THE FACTORS WHICH DETERMINE THE SPREAD OF HOOKWORM INFESTATION IN THE KARONGA AREA, NORTH NYASA.

The factors which determine the spread of Hookworm infestation fall under two classes, viz., A. Climatic conditions, and B. Conditions concerning the habits of the people; and a consideration of any district from these standpoints affords a rough guide to the amount of infestation likely to be found in the population.

A. Climatic Conditions.

(1) Geographic.

The North Nyasa district of Nyasaland (British Central Africa) is bounded on the north by Tanganyika Territory, on the east by Lake Nyasa, and on the west by North Eastern Rhodesia. The Government post with the central hospital for the district is at Karonga on the lake shore. It lies in latitude 10° S. and longitude 34°E. (See frontispiece map).

(2) Physiographic.

The main feature of this region of Africa is the Great Rift Valley,(5) which splits the high plateau of East Africa into two. That portion which runs through Nyasaland is occupied by Lake Nyasa, an inland sea, 360 miles long, by, on an average, 40 miles broad.

On account of the rift valley we find two entirely different/

different types of climate with different flora lying side by side. At the bottom of the rift along the lake shore, and 1,520 feet above sea level, there is an extremely hot strip of plain with palm trees, banana groves and rice fields, and beside it, and often looking immediately down on it, is the high plateau 4,000 to 5,000 feet above sea level, with warm days and cold nights and growing the homely bracken and bramble bush.

The effect of these two different climates upon the health of European officials is well recognised by the Government, which estimates leave at the rate of six days for every month of service in the Lake Stations, and at only five days for the healthier hill stations.

We are concerned more particularly with the northern portion of the lake shore plain watered by the three permanent rivers; the North Rukuru, the Lufira, and the Songwe. This area, forty miles long, by, on the average, six miles wide, is the country of the Wankondé tribe of the Bantu race. (See inset map). The plain has been formed by the rivers and partly by the lake, which has undergone various changes in its level throughout geological time. To the west, the plain is flanked by a barren waste of hills, stony and waterless, except at the places where the three permanent rivers cut their way through them by gorges.

3. Rainfall.

There is a well-defined wet season of four and a half months/

months from December to April with an annual rainfall of 50 inches at Karonga. The rains are much heavier at the end of the wet season in March and April than at the beginning.

4. Temperature.

The atmosphere is dry except during the wet season, when the humidity and heat can be very trying to Europeans. The mean annual temperature is 74°F., with extremes of 50°F. in June and 98°F. in November.

5. Drainage.

As in most tropical countries with a seasonal rainfall, flooding in the low-lying plains is an important feature of the wet season. The numerous stony river beds in the hills which carry no water in the dry season become raging torrents in the wet season, and cause widespread inundation of the plains. Even the three permanent rivers overflow when in spate, and, as silting up of their channels is common, they frequently change their courses, which results in extensive floods until new channels are cut. During my stay in Karonga the North Rukuru river has overflowed its banks every year, and it has changed its course twice.

The drainage of the plain is further hindered by the behaviour of the Lake, which has been rising steadily since 1914 owing to the stoppage of its only outflow, the Shiré river.

Every wet season the Lake rises owing to the increased precipitation, and it falls during the ensuing dry season by evaporation/

evaporation and outflow. In addition to this, it has been found that, in a cycle of eleven years, the mean level of the lake rises and falls. This is due to the fact that for about five years the amount lost during the dry season by evaporation and outflow is less than the amount gained in the wet season by precipitation, with the result that the lake rises. In the next five years the contrary happens, viz., the amount lost in the dry season by evaporation and outflow is greater than the amount gained in the wet season by precipitation, and the lake falls. The variable factor is evaporation, and it has been suggested that this is associated in some way with the cyclical variation in sunspot activity which may have a causal connection with periods of increased and decreased evaporation.(6) The river Shiré became silted up in 1914 at a period when the water level of the lake was low, and this normal eleven years' cycle of rise and fall of the average level of the water in the lake has been interfered with by the removal of the outflow factor. Evaporation which still varies cyclically over the years, does not, however, exceed precipitation in any year, and the lake level, rising about five feet in the wet season and falling only four and a quarter to four and a half feet in the dry season, shows an average rise every year.

Represented mathematically the changes are:-

Where E= evaporation

" O= outflow

" P= precipitation

Then/

Then the normal conditions are an alternation over eleven years of

$$E + O > P \text{ and } E + O < P$$

and the present conditions in the absence of outflow are:-

$E < P$, a condition which implies a constantly rising level of water in the lake.

The effects of this state of affairs can easily be imagined in an area where drainage conditions could never be described as good. Temporary marshes, which used to form behind the raised beaches during the wet season when the lake was high, have now become permanent. The soil, which at one time must have dried up completely within a month after the cessation of the rains, now remains waterlogged for two or three months in many places. Lake shore villages are disappearing into the lake, and the villagers, loth to leave, linger on surrounded by swamp until the rising water claims their huts.

During the wet season the whole appearance of the country is changed. To the north, between the Songwe and Lufira rivers, the whole plain is under water except for the raised beaches along the lake-side where the villages are situated, and the flooded area is used to cultivate rice. South of the Lufira, towards Karonga and beyond, the flooding is not so uniform, but there has been, even in my time, a very noticeable spread of rice cultivation into Karonga itself, whereas, formerly, it was confined to the belt between the Lufira and the Songwe.

I/

I have gone into the question of drainage somewhat fully, but it is with a definite reason as will be apparent later.

6. Soil.

The soil varies from a grey or brown loam to a sandy loam with small patches of clay here and there. It is extremely rich and this area is considered to be the most fertile part of the country.

7. Vegetation.

There is now no forest growth in this area and trees are confined to palms and big shade trees such as the wild fig and banyan, and, in the villages, the mango tree. Banana groves surrounding the villages are a constant feature of this district.

Warmth is one of the first essentials for the germination of Hookworm ova and the active life of the larvae. For this reason Ankylostomiasis, except for isolated outbreaks in mines in the temperate zone, is a disease of tropical and sub-tropical countries. Altitude, by lowering the temperature, has the same effect as latitude. Below 50°F. ova do not hatch and larvae do not reach the infective stage, while 122°F. is fatal to both ova and larvae in from one to five minutes.(7) McVail has found that at 98.4°F. the development of ova is almost totally inhibited.(8) Between these extremes it has been found that the larvae die in three weeks at 95°F., over 99 per cent die in six weeks at 80°F, while at 59°F. the rate of destruction is less and the/

the length of life greater.(9)

As regards temperature, Karonga district, in latitude 10°S. with a mean annual temperature of 74°F. and a lowest registered temperature of 50°F. offers excellent conditions all the year round. During the wet season the temperature ranges from 70°F. to 90°F. so that the effective life of the Hookworm larvae is likely to be about six weeks if other conditions are equally good.

Moisture is the next essential for the active life of the larvae, so that places with a low annual rainfall distributed throughout the year are generally unsuited, or, should the infestation gain a foothold, the amount will be found to be slight. The rays of the tropical sun in the absence of moisture kill larvae in a few hours. Even in moist soil it has been found that direct sunlight kills them in five days, while drying kills them rapidly, and alternate drying and moistening hastens death.(9) It will thus be evident that the number of days of rain in any month is important, and that a small annual rainfall of 30 inches, if confined to four months of the year, will provide suitable conditions of soil moisture during these months. Karonga with 50 inches of rain falling on about 90 days during four and a half months provides satisfactory conditions during these months.

The totally rainless seven and a half months must not be forgotten. Allowing one month for the soil to dry up, we have a period of six and a half months during which conditions are unsuitable for soil infestation with infective larvae, and consequently the/

the spread of human infestation will cease. Even Hookworms must die, and during these dry months a certain percentage of them are lost by infested people, thus preventing the addition of worms in a cumulative manner. Chandler[10] working in India states that with three months' dry weather about 50 per cent of the worms harboured are lost, with six months 60 per cent, and with nine months 65 per cent. The dry season thus has the effect of treatment, and it is safe to say that in countries with a short wet season and a long dry season the degree of human infestation will never be massive.

The dry season will be seen subsequently to be of great importance when mass treatment is considered.

A proof of Chandler's findings can be given by the rise and fall of Hookworm infested cases at Karonga hospital. It follows, that if people are not gaining any worms in the dry season but are actually losing them, their symptoms must abate, and the number of patients who attend hospital with symptoms suggestive of the disease must decrease. The following graph is based on figures taken from a paper of mine published previously,[11] and it shows the rise in the number of cases during the wet season, and the fall when dry conditions come.

① Period during which the habits of the people are favourable to massive soil infestation.

② Period during which the habits are less favourable

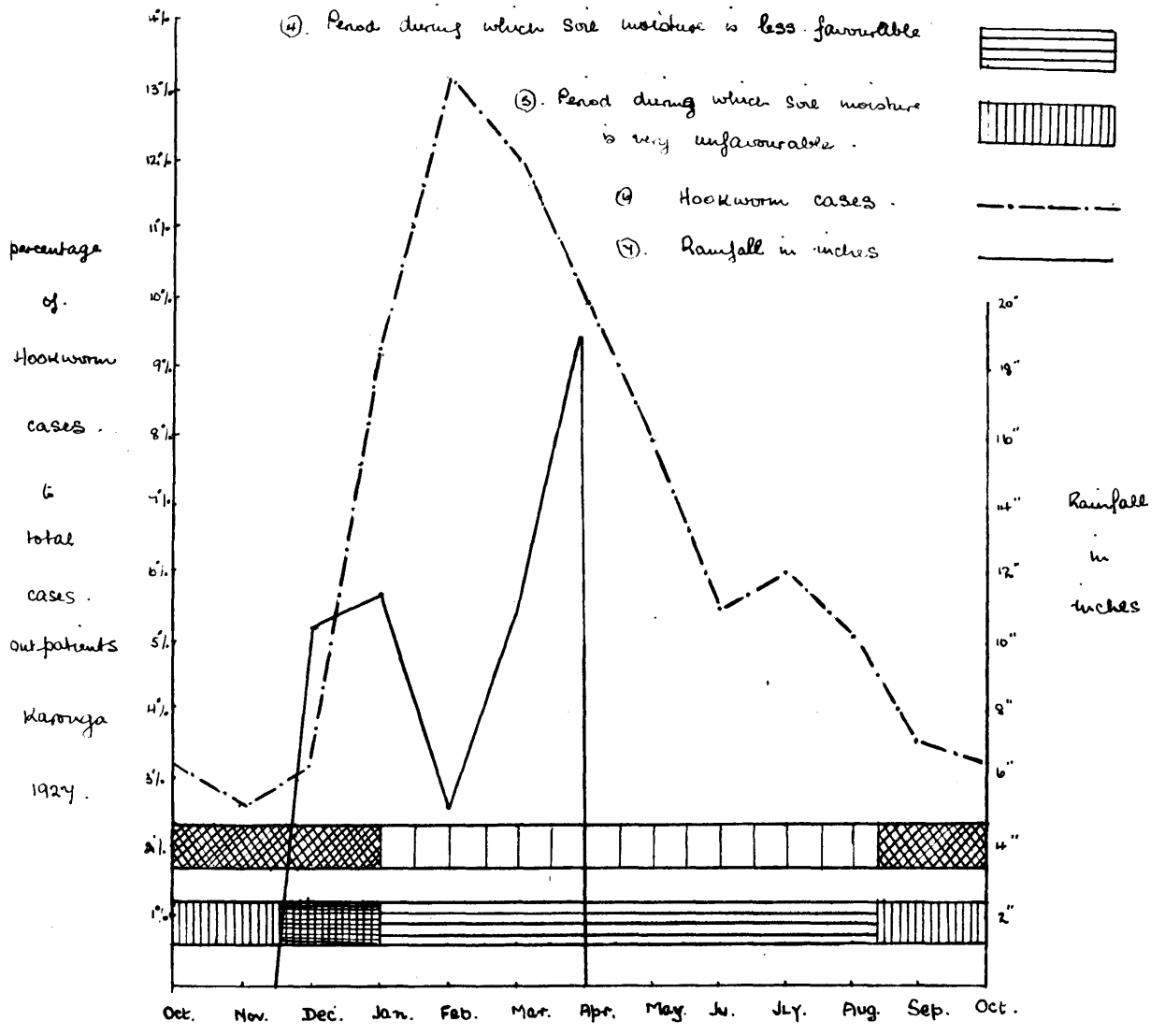
③. Period during which soil moisture is very favourable.

④. Period during which soil moisture is less favourable

⑤. Period during which soil moisture is very unfavourable.

⑥ Hookworm cases.

⑦. Rainfall in inches



A full consideration of this graph cannot be given here as the factors involved have not yet been considered. At the moment all I wish to show is that a marked rise in the number of cases occurs during the wet season.

Writers on the subject of Ankylostomiasis do not lay sufficient stress on drainage. As we have seen, the spread of the disease is dependent on the continuous moisture of the soil, and, although rain is responsible for this, it depends on drainage how long the soil will retain its moisture. The scrub covered stony foothills behind Karonga receive much more rain than the flats, but the water runs off quickly, and, with a day of tropical sunshine, the surface is dry. The importance of drainage is borne out by a comparison of the incidence of the infestation in different parts of Nyasaland where it has been determined.

Zomba.

Zomba, the capital of Nyasaland, is situated on the lower slopes of a mountain almost 7,000 feet high. The township is 3,000 feet above sea level, and it has a rainfall of 60 inches per annum with about 110 days of rain. The rains start in November and last as heavy rains for five months, but occasional showers occur up till July. The mean annual temperature is 69°F. and occasionally the temperature drops below 50°F. but this is in July when soil infestation is minimal. Actual Hookworm disease is not common. The incidence is 22.2 per cent.(12)

Mlanje.

Mlanje is the Government administrative centre of the tea growing area of Nyasaland. It is situated on the lower slopes of Mlanje mountain 10,000 feet high, and the actual station is

2,462/

2,462 feet above sea level. The rainfall is 80 inches per annum, falling on about 140 days. The wet season is from November to April, but showers fall every month except September and October. The mean annual temperature is 71°F., and the temperature falls below 50°F. rarely. The incidence of the Ankylostomiasis is 28.3 per cent and actual disease is not common.(13)

Port Herald.

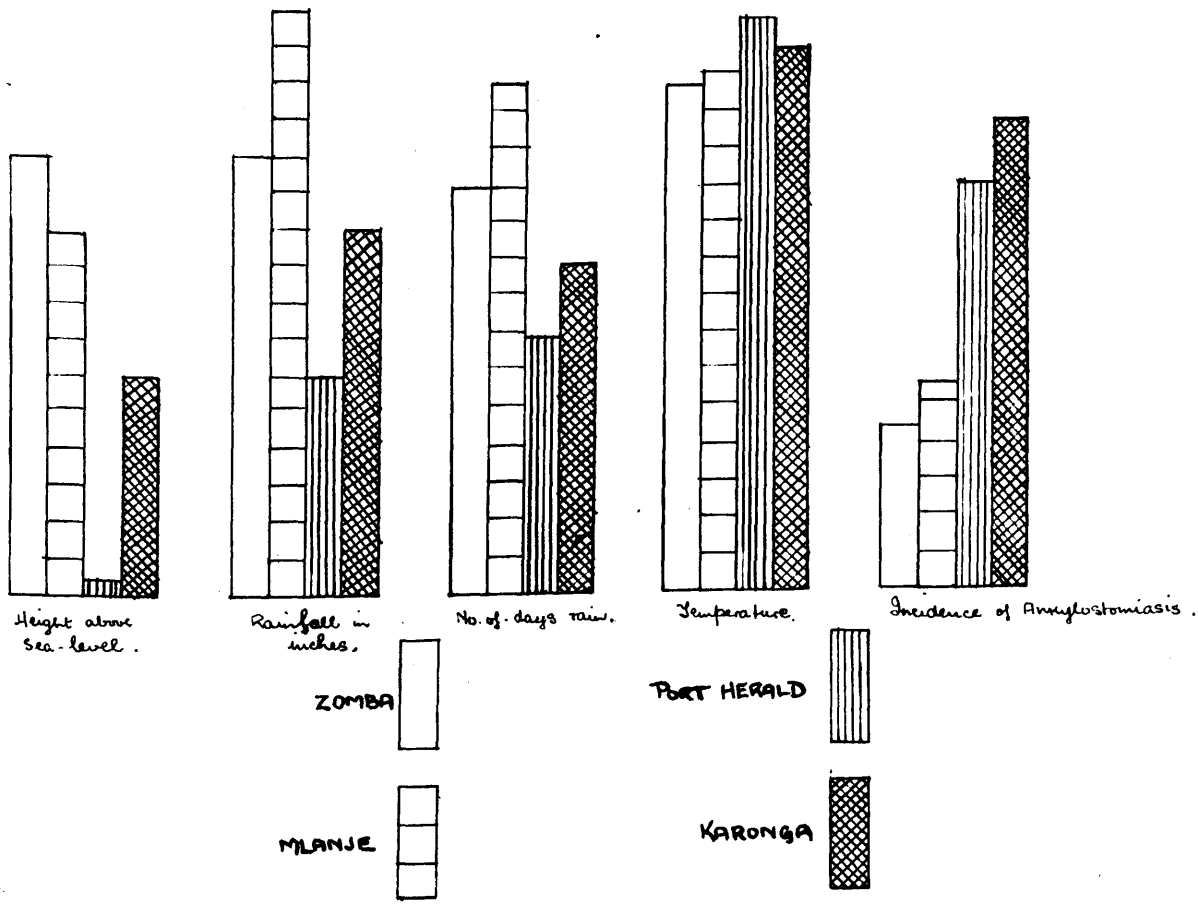
Port Herald is the administrative station situated on the Shiré river on the border of Portuguese East Africa. The country is flat and stands only 112 feet above sea level, as it also lies in the Great Rift Valley. The rainfall is 30 inches a year, falling on about 70 days. The wet season lasts about four and a half months and stops abruptly as in Karonga. The mean annual temperature is 78°F. and the temperature sometimes drops below 50°F. at the river. It is extremely hot during September, October and November when the temperature may reach 118°F. Gopsill, who made the Hookworm survey at Port Herald, examined smear preparations after gravity precipitation for 30 minutes, whereas the figures for Zomba and Mlanje were from simple smear examinations. Allowing a 25 per cent reduction, which should be ample, for the method used by Gopsill, his figure for incidence, 74.2 per cent, becomes 55 per cent. Hookworm disease is frequent at Port Herald.(14)

Karonga.

Situated/

Situated on an alluvial plain along the lake shore Karonga is 1,520 feet above sea level. The rainfall is 50 inches per annum falling on 90 days. The mean annual temperature is 74°F. with a minimum of 50°F. The wet season is four and a half months. Using smear preparations but examining four before accepting a negative result I found the incidence to be 89.8 per cent in 1930, but in 1927 examining only one smear the incidence was 64 per cent, and I use the latter figure for the comparison. Hookworm disease is very frequent at Karonga.

The foregoing figures are represented graphically in the following diagrams.



The conditions in Zomba and Mlanje from the point of view of the amount of rain and the number of days on which it falls are much more favourable to the spread of Ankylostomiasis. The differencesin the mean annual temperature are very slight, and, as the temperature during the wet season is higher than the mean annual, all will be above 70°F. and therefore suited to the active life of larvae during the period of effective spread of the infestation. Soil pollution is at a maximum in all except Karonga, where latrines are used to a slight degree.

What then is the explanation of this difference in incidence and the known fact that as a clinical disease Hookworm infestation is uncommon in Zomba and Mlanje, but common in Port Herald and extremely common in Karonga?

Augustine has shown that larvae are confined, especially to the upper half inch of the soil, and are not found deeper than four inches.(15) They also tend to creep up twigs and leaves on the surface of the ground provided there is a film of surface moisture.(16) Now it has been found that heavy rain is a potent factor in reducing soil infestation by washing away pollution and infested soil,(17) and, as Zomba and Mlanje occupy the well-drained and even steep slopes of mountain sides, the washing action of the rain must be considerably greater than on the flat plains at Port Herald and Karonga. Again, it was mentioned that drying and alternate drying and moistening of the soil hasten the death of larvae. This probably has some effect in Zomba and Mlanje, where the rain runs off quickly and the

upper/

upper layers of the soil soon dry up. In Port Herald and Karonga, where drainage is poor and the soil deep, the rain cannot easily run off and the soil is permanently moist during the rains.

Other factors unknown may come into play, but the main one is undoubtedly drainage, and this explains the low incidence in mountainous districts, a fact at which some writers have expressed surprise.(18)

Additional proof of the importance of drainage is afforded by a comparison of the findings of Conran(19) at Karonga in 1913 and my own in 1927. Conran examined two villages at the lake shore close to the ones I examined, and two further inland. He found that the rate of incidence of Hookworm and Ascaris was greater in the two inland villages and his figures therefore include villages where there is a higher incidence than in the villages he examined adjacent to mine.

	Conran 1913. Incidence.	Watson 1927. Incidence.
Hookworm	42.67%	64%
Schistosoma	16.0%	15%
Ascaris	11.3%	5%
Trichocephalus	1.3%	1%
Taenia	-	4%

For the villages adjacent to the ones I examined on the lake shore Conran gave a figure of 3 per cent for the incidence of Ascaris infestation. This approximates to my figure of 5 per cent. Since the war, a native meat market has been started in Karonga, and the increased consumption of meat may be responsible for the difference in our findings for infestation with Tapeworm.

This rise in the incidence of Ankylostomiasis from 42 per cent to 64 per cent has occurred in spite of the introduction of pit latrines in Karonga district after the war. The only change I can find in the physical conditions between 1913 and 1927 is that in 1913-1914 the lake was at its lowest, and it has been rising continuously since then. The result of this constantly rising lake is that, if it does not provide universally moist conditions as do the rains, it has the effect of prolonging moist conditions of the soil and so keeps up a degree of soil infestation. Again, it lessens considerably the effective dry period during which those infested are losing their worms by natural elimination.

It has been found that soils differ in their suitability as culture media for Hookworm larvae. Stoll, (20) while testing various soils, found that the following percentages of larvae were recovered from a known number of ova.

1./

1. From pure faeces.....15%
2. From a mixture of faeces and clay..... 2.74%
3. " " " " " " sand.....26%
4. " " " " " " loam.....26%
5. " " " " " " humus (under banana groves).65.22%
6. " " " " " " charcoal (control).....16.25%

As will be shown later, the most constantly polluted area at all times of the year in Karonga is the village banana grove, where, in addition to optimum soil conditions, we have optimum moisture and shade, as the sun practically never penetrates the grove. The patchy distribution of clay and the almost universal presence of loams and sandy loams with good shade in the wet season has been noted in Karonga, so that all told, Karonga provides excellent soil and shade conditions for the active life of larvae during the wet season.

B. The Life and Habits of the People.

Population.

In a tropical country with a seasonal rainfall the grouping of the population is determined by the position of the sources of permanent water supply, and the density of the population depends on the amount of water available at such sources coupled with good soil conditions. These factors depend in turn upon the geology of the country.(21) Accordingly, in North/

North Nyasa we find the population concentrated along the lake shore within half a mile of the lake, and along the banks of the permanent rivers. As the soil is rich and the water supply ample, the population is dense. The total area of the district is 4,478 square miles and the population is 47,380, but in that small portion of the lake shore plain we are concerned with there are 18,000 people. (See inset map).

Characteristics of the Tribe.

The natives of the Wankonde tribe are tall and plump bodied and primitive in the sense that they are free from any European habits of life. The first thing one notices about them is their comparative nakedness compared with other tribes. The women go about clad in a three inch strip of bark cloth at all times, while the men, when working, wear a very short kilt made from a banana leaf which can be renewed daily. For dress occasions the men favour a length of black twill draped over the body in the fashion of the Roman toga. Formerly, entirely a pastoral people, they have become increasingly agricultural in addition, since the advent of settled times associated with British rule. They cherish their cattle to the extent of housing them with their own families in well-built huts of wattle and daub; one end for the cattle and the other for the family. They lay out their villages neatly with the houses in proper alignment and each village is surrounded by the extensive banana grove.

In character they are gentle, mannerly and very home-loving/

home-loving, and they have a stronger sense of tribal discipline than is found elsewhere in Nyasaland. Their chieftainship is of the nature of a priest-kingship. The chief is chosen by a special hereditary body (the Makambara), who pick from the royal clan a suitable man. Before the advent of Europeans, the old chief, when his powers were failing, was secretly suffocated, and the new chief put in his place. Nowadays, the precedent of retiring the old chief has been established, and the first retired chief is still living at Karonga. They have their own well-developed system of law, and the chief's court is used as the highest court of appeal.

The Government, within the last two years, has officially recognised the chief's powers, as the first step in Nyasaland of the introduction of Indirect Rule through the chiefs. Under Direct Rule one had to deal with the population as individuals which meant but slow progress in sanitary matters, but now I have great hopes, that, if the chief and his councillors become interested in sanitation, they will do what I was unable to do.

As the Wankonde are contented within their own tribal borders they do not seek work readily with Europeans. Planters find them lazy and will not employ them, and prefer, even in North Nyasa, to employ men from other tribes. There is no doubt that the accusation is true, but my own opinion is that the Wankonde are temperamentally unsuited for labouring work, and that their inferiority physically is due to the fact that Hookworm disease is so common amongst them.

Crops/

Crops.

From the rich soil of the plain the people harvest abundant crops of rice, maize and millet, together with cassava, sweet potatoes, beans, and ground-nuts. About half of the rice crop is exported to other parts of Nyasaland. There is also a small trade in ghee (clarified butter). Their main period of activity in agriculture is from November to July when the rice is harvested, thus coinciding with the wet season and the period of maximum soil infestation.

Diet.

The Wankonde are allowed to be the best fed tribe in the country, both as regards quality and quantity of the food eaten. Protein, which is largely deficient in the diet of other tribes, is here taken in the form of curdled milk, and, as these 18,000 people own 13,500 head of cattle, there is no lack of milk. Fish is eaten largely by the lake shore people and to a less extent by the riverside people whose fishing activities are confined to the wet season, when runs of a fish not unlike our salmon take place. A limited quantity of meat is sold at 2d. per pound in the market at Karonga, but it is brought mainly by the paid employees of Government, trading concerns and Missions.

The main fault in their diet is the lack of fresh uncooked vegetables or fruit. Bananas are unfortunately plucked green, peeled and boiled like our own potatoes. Typical meals would/

would be boiled bananas and curdled milk, or a very thick porridge of maize meal or rice eaten with a relish of boiled beans or boiled native spinach. The mango, the main fruit, has a very short season of six weeks.

In view of the two main diseases of the lake shore, Malaria and Hookworm, it is to be regretted that a diet richer in iron containing proteins is not available. Meat is a delicacy to the average villager associated with feasts and comparable to our wedding cakes as regards the number of times it is eaten. It may seem strange to Europeans that meat is a delicacy, when it has been said that the people are rich in cattle; but it must be remembered that the African determines wealth by the number of cattle owned, and would never dream of parting with a beast unless seriously pressed for money. Cattle are bound up in the marriage customs of the tribe and their legal procedure makes it evident that their laws did not envisage such a thing as the sale of cattle for slaughter. The killing of an ox is therefore almost the prerogative of a chief to be done only on special occasions of a public nature.

Sanitary Habits.

The sanitary habit of the African is, soon after rising in the morning, to seek a secluded place well screened from the eyes of others to defaecate. As there is a taboo about witnessing a senior relative in the act, all, except the very young, are careful to use the best possible cover available to prevent such

a/

a happening. The season of the year plays an important part in this search for concealment.

In September and October the grass and bush are fired throughout the plain, and, as the fires reach up to the banana groves surrounding the village, suitable cover other than the groves is at a premium until about six weeks after the rains have commenced, when the new growth of grass and crops is sufficiently high to afford universal cover. During this period I have found the following sites in common use:-

(1) The banana grove.

(2) The grass, bush and trees along the river banks and along the lake shore, which, being more moist from the proximity of water, usually escape burning.

(3) The immediate neighbourhood of big trees.

(4) The reeds at the edges of swamps or what were swamps in the wet season.

(5) Isolated patches of bush which escape burning owing to being cut off by villages or banana groves from the bush of the plain proper.

The first duty of the women in the morning is to go and draw water, and, as the natural desire to go to stool often coincides with this duty, the bush at river banks and along the shore are favourite sites with the women. There is the added advantage that the menfolk are absent on these occasions.

After dark, which comes at six o'clock, that portion of the/

the banana grove nearest the hut is a commonly used site, as the Africans have no candles or lamps, and naturally do not care to go far afield after dark for fear of snakes.

With such a limited number of places offering concealment, concentrated soil pollution is the rule during the hot dry season and the first six weeks of the rains, and one can count stools by the score in any of the above places. From the point of view of the spread of Hookworm infestation these "natural latrines" are of no great importance in the hot dry months of September, October and November, but, as they are used during the first six weeks of the wet season, their importance is great as very heavy soil infestation must follow as soon as the rains break. It has been proved that Hookworm larvae have but feeble powers of migration, spreading out only four inches from the centre of soil inoculation,(22) so that it is necessary for the bare feet of the people to come into close contact with the actual site of defaecation before infestation follows. One would naturally think that the native avoids treading near an obvious stool, and so he does, but in the tropics stools disappear rapidly in a few days from the action of rain and insects, such as dung beetles and the larvae of flies, and there is nothing left to warn the native that the soil he is walking on or squatting on while he is defaecating is infested with larvae which will continue to live there for about six weeks.(23)

In the second half of the wet season and thereafter until the grazing cattle or the grass fires of the next dry season destroy/

destroy the grass and bush, the choice of sites is unlimited round the villages, along the paths, and in the gardens where the people may be working. On the whole, the soil pollution will be in the vicinity of the villages, but as the choice is so wide the chance of using exactly the same places as others is greatly diminished.

Two other factors come into play which help a little to make the second half of the rains less suitable than the first:- (1) The heavier rains occur in March and April, and, to a degree much more limited than in the hill areas, faeces and polluted soil are washed away, thus lessening the concentration of soil infestation. (2) The heavy rains combined with flooding cause a waterlogged condition of the soil in many places, and it has been shown by Payne(24) that a waterlogged soil compared with a uniformly moist soil prevents migration of the larvae and hastens their death.

We have now sufficient data to examine more fully the graph of Hookworm infested cases attending hospital for treatment. It will be noticed that the rise in the number of cases does not start with the commencement of the rains. By the end of December there have been ten inches of rain, but the incidence of Hookworm is still only 3.2 per cent. The explanation which suggests itself is that, although people are being infested in the most favourable period of the early rains as I have shown, time is needed for (1) the development of ova into infective larvae, and (2) for the devious journey of these infective larvae through the/

the human body to the duodenum where they reach full adult development. We must therefore allow a minimum period of a month from the stage of the egg to that of the adult worm fixed to the duodenal mucosa and causing symptoms. Accordingly, it is in January that the abrupt rise in the number of cases takes place. This rise continues as conditions are extremely favourable, but at the end of January somewhere, six weeks after the commencement of the rains, the change from the use of localised sites of defaecation to those uniformly distributed sites takes place. It seems reasonable, therefore, to expect a cessation of the rise in the number of cases which should show itself at the earliest in the beginning of March, one month after the change. This actually occurs, as there is a slight fall in the curve after February. Later, towards the end of March and in April, the additional factors of waterlogging of the soil and the cleansing action of the heavy rains also play a part in the cessation of any further rise in the number of cases, and, although conditions are still favourable, as is shown by the relatively high percentage of cases, optimum conditions for the spread of the disease are absent and the curve of the graph is steadily downwards. Entirely unfavourable conditions for soil infestation are not reached until the beginning of August when the hot dry weather sets in and the lake begins to fall rapidly. The less abrupt fall after the rains are over may possibly be explained on the grounds that (1) owing to the high level of the lake the

soil is still sufficiently moist in places to permit of soil infestation, and (2) a certain number of people actually infested earlier are but now developing symptoms, or, being free from their pressing agricultural duties, are now able to attend the hospital.

The percentages for September, October, November and December show little or no difference, and represent probably the true percentages of massive infestation in the district which is not lightened by the natural loss of worms which occurs in the hot dry season.

The aforementioned sites do not exhaust all the possibilities of soil infestation. Baermann,[25] who first investigated the question of soil infestation, found that the earth and mud around water pots in huts and on verandahs are frequently infested. Augustine,[22] in the soil scraped from the shoes of men passing through infested areas, found larvae in numbers of from 2 to 344 in different people, and it is not to be wondered at that even the mud floors of the huts become infested. Again young children and infants defaecate anywhere and at any time, and as most of them harbour Hookworms, practically no place in and around a village is safe during the wet season.

It may appear strange that infants are actually infested, but as soon as a baby can sit up the mother is accustomed to take the child off her back and lay it down when she is busy. This happens even when she is defaecating. I have actually been called to a case of retained placenta and found the woman squatting under/

under a big tree in the bush near the village with the still attached infant lying on the ground, and in the vicinity obvious stools lying about. The custom of the women in labour is to go out into the bush in this manner. At slightly greater ages, when the crawling and toddling stage is reached, such babies can easily bring a comparatively large surface of the body into contact with infested soil.

The sanitary habit of the African in Nyasaland can be summed up in the literal translation of his verb "to defaecate" which is "to go to the bush." In fact the process has gone so far that Europeans have adopted the word bush as a synonym for defaecate, and it is common to hear Europeans ask their children if they have "bushed" to-day. Natives have even adopted the word bush, and changed it into a noun "bushu."

C. The Use of Pit Latrines.

It has already been mentioned that the use of pit latrines was instituted after the war in North Nyasa, so that they must be included in a consideration of the sanitary habits of the people. The success of this measure can best be judged by the increase of Hookworm infestation since 1913. As built by the villagers of this district pit latrines are ugly in appearance, indescribably filthy inside, and evil-smelling in the extreme. The type used is a simple pit two and a half feet in diameter and/

and as deep as local circumstances permit. Logs are laid over the pit and then "mudded" over leaving a suitably sized hole over which to squat. A small hut of wattle and daub with a grass roof is built round the pit. Properly built to withstand the rains, these latrines are quite good, as can be seen when inspecting one used by an educated native, but in the villages the work is scamped. The roofs leak and the walls have insufficient foundations, so that, when the rains come, they collapse.

The following table shows what may happen. The villages mentioned had been reported as dirty and insanitary and the headmen had been admonished by the District Commissioner, who sent a policeman with my sanitary inspector to see the villages cleaned up. The second column shows the number of latrines built by October after the "clean-up," and the third shows the numbers remaining in June, 1931, after the wet season.

Village.	No. of huts.	No. of latrines October, 1930.	No. of latrines. June, 1931.
Kalongolero	75	70	9
Mwangululugulu	106	90	15
Moses	20	20	10
Mwantende	102	90	9

I cannot lay the entire blame on the villagers, however, as there is no doubt that in the rice area in the north a rise of the/

the subsoil water to within a foot of the surface occurs in many villages in the wet season at the period of high lake level, and under such conditions it is not surprising that pits cave in and the superstructures collapse.

Except in the hands of educated natives, pit latrines are a failure, and, in my opinion, a possible factor in the spread of the disease. Faeces are deposited anywhere except down the hole, and, as the latrines are built a short distance from the huts, they afford cover often nearer than natural cover, with the consequence that it is easy to use them without taking the trouble to squat accurately over the opening. Invariably with a leaking roof, the soil is moist inside, and they then become Hookworm traps for the users. In police lines, or in labour lines on estates where supervision is possible, their use is cheap and effective, but in villages where no supervision is at present possible their use will be a danger until such times as the people are sufficiently educated to use them properly.

I gave as my reason for the increase of Hookworm disease in Karonga the lack of drainage consequent upon the continuous rise of the lake, but it is possible that the improper use of pit latrines is an additional factor, for it is well known that Ankylostomiasis in many parts of the world is a privy infestation and the soil in the vicinity of such places has been shown to be an important site of soil infestation.(24)

IV. HUMAN INFESTATION IN THE KARONGA AREA.

A. Methods of determining the Degree of Human Infestation.

The only exact way to determine the rate and depth of human infestation is to use the method of "worm counts" after treatment. This, however, is a slow, laborious process and one more suited to the whole-time investigator than to a medical officer with his normal duties to carry out. The next available exact means is the estimation of the number of ova in a definite amount of faeces by concentration methods, such as those associated with the names of Lane and Stoll. Lane's Direct Centrifugal Flotation (D.C.F.)[26] method is reputed to detect ova in the faeces from a single female Hookworm living in the bowel. The counts of ova can be correlated to the number of worms harboured. Again the medical officer will probably find in Central Africa that he is not provided with the appropriate apparatus for this method; or, if he had it, he would probably not find sufficient time to spare from his other duties to investigate the conditions of the people so exactly. As I had not the apparatus, I had to fall back on less accurate methods, the first of which was the determination of incidence of the infestation by the examination of simple smear preparations.

While this method will give positive results in all cases likely to harbour a sufficient number of worms to cause symptoms, it does not distinguish between very light and massive infestations, and/

and is therefore fallacious as a guide to the degree of infestation in a population.(27) One worker resurveying an area treated five years previously found that the incidence, which had been 29.8 per cent, was now 21.2 per cent, and he concluded that reversion had taken place.(28) Smillie, in the fourth year after a successful Hookworm campaign of treatment which included the installation of latrines in over 80 per cent of the houses, found that the incidence showed but little change, viz., from 71.2 per cent to 70.2 per cent. He was dissatisfied with this result, and, making a complete examination by the worm count method, found that the average worm count of people who had been treated was 14 only, while in controls, who had not received the treatment, the number of worms averaged 329 per person.(29) He thus showed that an apparently poor result, as judged from figures of incidence, was in reality an excellent result by the method of worm counts, and that the Hookworm campaign was still successful after the lapse of three years.

There is another method of arriving at a judgment of the degree of infestation, that is, by estimating the haemoglobin content of the blood of infested people. Stoll has found a direct correspondence between the size of egg counts and the loss of haemoglobin.(30) It might be argued that the presence of malaria in Karonga area might render the haemoglobin readings valueless, but no evidence has yet been found that malaria conceals the effects of Hookworm disease. Darling and his co-workers have found/

found that the ratio of the haemoglobin to the number of worms harboured is the same in malarial and non-malarial groups.(31)

The correlation of haemoglobin to the number of worms harboured cannot be given exactly for an individual, as age, sex, diet, and work play an important part in determining the haemopoietic response of the individual to the infestation. Generally speaking, young adults are better able to compensate themselves for the loss of haemoglobin, and men more than women. A rich diet, especially of red meat, will obviously help the individual and an easy life will aid. Light infestations up to 25 worms do not appear to have any effect on the haemoglobin of healthy individuals, as such people are well able to make good the loss which is occurring. Smillie is of the opinion that while 25 worms will not affect the haemoglobin, 50 to 100 will,(32) and Darling states that 8 worms in a boy and 12 worms in a man cause a loss of 1 per cent haemoglobin when the number of worms is over 100 and 200 respectively.(31)

Whatever be the exact relationship, there is no doubt about the loss of haemoglobin, and a statement of the average haemoglobin content of the blood of the people conveys more regarding the health of the population than a statement of the number of worms harboured. I made use of this method at Karonga as a simple way of determining the effect of Hookworm infestation in the population.

B. A Hookworm Investigation, 1927.

In 1927, not long after I went to Karonga, I investigated the condition of the people with regard to Hookworm infestation, as it seemed to me that the numbers of cases attending hospital were very high compared with numbers at Zomba, where I was stationed previously. From my previous paper,(11) which gave the results of that investigation, I extract the following data:-

The Incidence of Ankylostomiasis, examining one smear preparation per stool of 100 women, was 64 per cent.

The following table gives readings of haemoglobin taken on Tallquist's scale:-

TABLE I.

No.examined.	Sex.	Highest Hb.%.	Lowest Hb.%.	Average Hb.%
100	M.	80	45	67.95
100	F.	80	15	62.6

These figures show a degree of anaemia, which, while it would not be considered severe in an individual, is rather alarming for a community. As all the people examined were fully adult and were not suffering from active malaria, as far as could be judged by the absence of spleens reaching to the costal margin, the figures probably represent anaemia largely produced by Hookworm infestation.

As/

As a comparison, the percentages of haemoglobin found in young male adults at Livingstonia Mission are given. I was permitted to take these readings by the courtesy of Dr. G. B. Burnett. They show the much better condition of educated natives leading sanitary lives. Diet is not a factor in the difference between the groups, as these young men are, if anything, not so well fed as the Wankonde, who have the important items of milk and rice in their diet.

TABLE II.

Young adults at Livingstonia Mission.

No. examined.	Highest Hb.%.	Lowest Hb.%.	Average Hb.%.
55	90	60	83.9

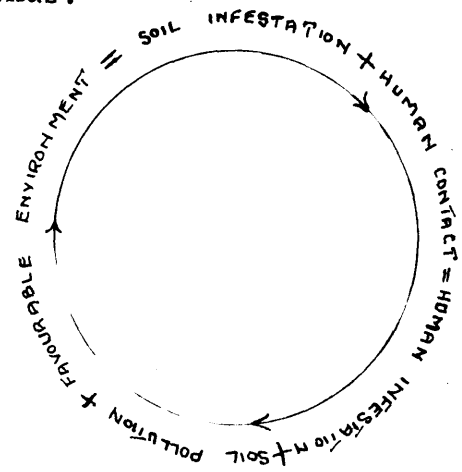
Finally, although the numbers are very few, I give the haemoglobin values of the Europeans stationed at Karonga.

TABLE III.

No. examined.	Sex.	Highest Hb.%.	Lowest Hb.%.	Average Hb.%.
7	M.	95	87	89.3
5	F.	90	84	85.8

V. A HOOKWORM CAMPAIGN AND ITS RESULTS.

The vicious circle of Hookworm infestation has been described by Cort thus:-(33)



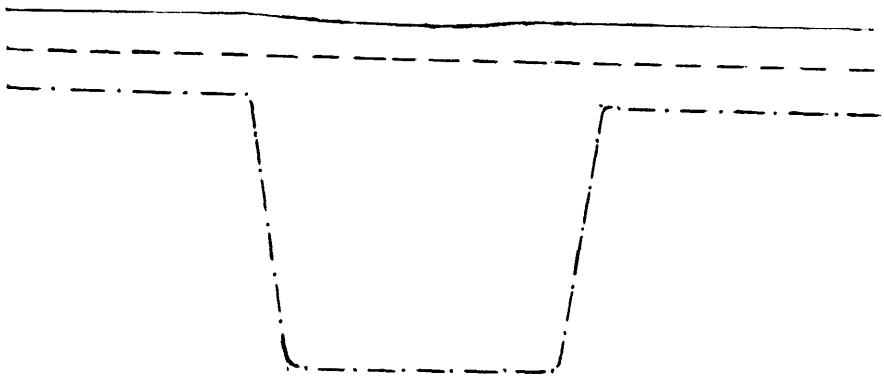
In Karonga this vicious circle has been established. There is, however, a weak point in this circle, viz., when the environment is unfavourable, as it is in Karonga during September, October and November. The time, therefore, to conduct a mass treatment campaign is during these months when soil infestation is minimal. The people treated will be rid of their worms at a time when soil pollution will not result in soil infestation, and, when the wet season arrives, the amount of soil infestation which will result from treated people will be relatively light. Making use of Cort's graphs,(33) the conditions at Karonga are seen in (1).

———————————— human infestation.

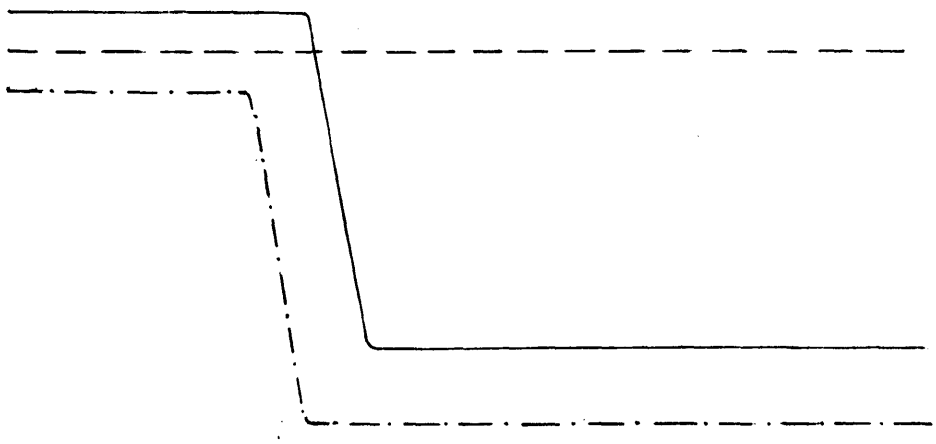
— — — — — — — — — — — — soil pollution.

—.—.—.—.—.—.—.—.— soil infestation.

(1) Uncontrolled area like Karonga with soil infestation reduced to a minimum by the dry season.



(2) The effect of mass treatment during the period of low soil infestation in the dry season.



Actually, it is impossible to treat all the infested people, as it is also impossible to remove all the worms by a single treatment, so that there will be a step like return over years to previous conditions of human infestation after one mass treatment in the dry season.

With a view to a small experimental campaign, I made a survey of three villages which would represent the various conditions found in the Karonga area, and after treatment, and after the/

the ensuing wet season, when the people would have experienced their first reinfection, I examined them again to assess the value of the campaign. I hoped by this method to get some results which would be of value in estimating the ease or otherwise of reinfestation, and also from them to elicit something which might be a guide to the future control of the disease in the district.

Village A. Mawembe.

This village is representative of the southern half of the area. It is situated on a definite ridge raised four or five feet above the swampy ground to the north and south. The water supply is from the lake. A little rice is grown, but the main cereal is maize. This crop failed in the heavy wet season of 1929-1930, so that from the time of examination, August 1930, until three months before the second examination, June 1931, there was a moderate degree of famine in this village as elsewhere in the southern half of the area. The soil is a sandy loam and large banana groves are present.

Village B. Fundi.

This village is situated on an old raised, sandy beach at the lake side and its water supply is from the lake. Immediately behind the village to the west there is a huge swamp which does not dry up till August. Fishing is the main occupation. The villagers suffered slightly from the famine, but it was noticeable that/

that during this famine they were unwilling to sell fish unless for double the price, showing that they were relying on a fish diet to tide them over the difficulty. This village is representative of the villages all along the coast which mostly occupy old raised beaches.

Village C. Mwaulambo.

This village is situated below the gorge where the Lufira river breaks through the hills, and a few hundred yards above the place where the river breaks up to form a delta. It is on the western boundary of the rice area. The actual site of the village is good, especially the western end, which is on a definite slope. The eastern end is only a few feet above the level of the flood height of the river which spreads out greatly in the wet season. When the river recedes, there is a definite low-lying stretch of ground about 200 yards broad between the village and the river, and the excellent alluvial soil in this situation is sufficiently moist all the year to grow abundant crops, even at the height of the dry season. This village did not suffer from famine. It is representative of the villages along the banks of the rivers and along the edge of the foothills.

I examined adult women only, knowing that I would be able to re-examine most of them, because the women do not move away from home so much as the men. Adults only were examined in order to minimise the chances of complicating the results by the possible presence of active malaria likely to cause anaemia.

A native assistant trained to the use of the microscope sat at a table alongside me. Each woman handed over her stool specimen and he labelled it. Selecting one, he took up a piece on a match stick, emulsified it on a glass slide with a few drops of water, placed on the cover glass, and examined it. Whenever he found Hookworm ova he demonstrated them to me. If his first and second slides were negative he passed on to the next stool, and, when I had finished my blood counts, I examined a third and fourth slide of the negative specimens. Thus a negative result meant that four smear preparations were examined, and, by this method, a greater degree of accuracy was obtained compared with 1927. The blood counts and the haemoglobin estimations were done by myself. Tallquist's scale was again used.

The first examinations were carried out in August and September, 1930, the Hookworm campaign running concurrently. The examinations were made in June and July, 1931, after re-exposure of the population to infestation in the wet season of 1930-1931. The results are contained in Table IV.

TABLE IV.

Village.	No. examined.	No. Pos	No. Neg.	% Pos.	% Hb.	No. examined.	No. Pos.	No. Neg.	% Pos.	% Hb.
A.	57	53	4	93	65.8	57	44	13	77.2	71.3
B.	28	25	3	89.3	61.8	28	22	6	78.6	72.3
C.	33	26	7	78.8	61.2	33	17	16	51.5	75.4
Totals & Averages	118	104	14	88.1	62.9	118	83	35	70.3	73.0

The reduction from 88.1 per cent to 70.3 per cent does not at first sight appear to be an excellent result, but we must remember the fallacy of judging by incidence only. The general consensus of opinion is that a 60 minim dose of carbon tetrachloride followed by epsom salts in two hours removes 95 per cent of the total number of worms harboured, and that actually in 50 per cent of the cases all the worms are expelled.(34) Docherty gives 58.2 per cent cures and 98 per cent elimination of worms.(35) Assuming a 50 per cent cure, then, my 104 positive cases become 52 and this number becomes 83 after the ensuing wet season, a rise of 31. The reinfestation rate is therefore 60 per cent. This is rather a startling rate and suggests that conditions for soil infestation must be very suitable in the wet season and the habits of the people such that they afford maximum contact with soil infestation.

However bad the reinfestation rate may be, it is known that on the average worms are acquired slowly over years.(32) Darling gives twelve worms a year as the rate at which worms are acquired in Java.(30)

Turning to the haemoglobin results, we find more enlightening figures, which show the improvement following the presumed loss of 98 per cent of the worms, even allowing for subsequent slight reinfestation. A rise in the haemoglobin value of 10.1 per cent affords a much better idea of the profound effect treatment has on the health of the people, and incidentally it proves/

proves that Hookworm disease is the cause of serious ill-health among the population of Karonga. This rise also suggests that reinfestation, while easy, has not resulted in reinfestation with massive doses of worms likely to have serious effects.

The following table gives the grouping of the haemoglobin value before and after treatment and re-exposure. It shows much better than the statement of averages how poor the blood of the population was before treatment and how much improved after treatment.

TABLE V.

Haemoglobin 1930.						
31-40%	41-50%	51-60%	61-70%	71-80%	81-90%	91-100%
1	9	44	41	23	-	-
.84%	7.6%	37.3%	34.7%	19.5%	-	-
Haemoglobin 1931.						
31-40%	41-50%	51-60%	61-70%	71-80%	81-90%	91-100%
-	1	6	26	81	4	-
-	.84%	5.1%	22%	68.6%	3.4%	-

In Hookworm disease the loss of haemoglobin is greater than the loss in the number of red cells, thus giving a low colour/

colour index. The following table shows the full counts before and after treatment, and they differ in no way, as they show the relatively greater rise in the haemoglobin after treatment with a consequent rise in the colour index. While the blood after treatment cannot be considered normal, probably due to the presence of malaria, it does complete the picture of the good effects of treatment.

TABLE VI.

Year.	No. examined.	Aver. Hb.%.	Average red cell count	C.I.
1930	118	62.9	4,219,588	.76
1931	118	73.0	4,426,241	.86

Turning to the figures for the different villages, Mwaulambo, Village C., presents some differences from the other two, but, as the numbers examined in each village are not large, it is perhaps wrong to think this difference has any special significance. The western end of the village, however, is on a definite slope where the foothills start and many of the houses are actually built on the outcrop of the soft sandstone, so that possibly a higher percentage escape infestations; while the eastern end of the village is flanked by moist soil conditions all the year round and may have heavy infestations. After treatment the distinctly better feeding of these villagers may account in some measure for the relatively greater rise in the/

the haemoglobin readings.

Conclusion.

The results as a whole show clearly the benefits of mass treatment. The haemoglobin value of the blood has proved itself a useful index of the degree of infestations and a useful test of the success of mass treatment. In order to determine if these figures could be applied to the general population of the plain who were not examined, but received the treatment, I examined the forty-nine adult females of another village which had features common to villages A and B. The average haemoglobin content of the blood of these women was 73.2 per cent, and one blood gave a reading of 90 per cent, and was the first case I had examined on the lake shore of such a high reading, in either man or woman.

VI. FUTURE WORK IN NORTH NYASA.

Pit latrines as used by the villagers are definitely not a controlling factor in the prevention of Hookworm infestation in the North Nyasa lake shore plain, so that, while a step in the right direction, they must on no account be relied upon in any scheme for the control of the infestation. While not in any way abating the advocacy of their use, I think it should be left to the initiative of individual villagers to build and use them, and the medical officer could confine his efforts more profitably to inducing the chief and his councillors/

councillors to take up sanitation as a tribal matter. In this way it might be possible to develop some strong public feeling on the subject. Such a feeling regarding sanitation is present amongst the educated Africans, and, if it could be harnessed, any scheme originating from tribal sources would be received with greater sympathy and attention than would schemes brought into force by alien administrators. In this way no false optimism would be engendered as has occurred, and, if anyone were anxious to determine the progress from time to time, a count of the latrines in use would provide an answer.

As regards the rice area, I suggest that a small experiment might be carried out to introduce the Chinese method of fertilising rice by the use of stored night soil.(36) As has been stated previously, pure faeces is the poorest culture medium for Hookworm ova and larvae, and Cort and his co-workers in China have found that people in the rice flats have practically no Hookworm infestation owing to this method of storage, even although in surrounding areas where the mulberry tree is cultivated Hookworm infestation is heavy.(37)(38)(39) Pit latrines are hopeless in the rice area of North Nyasa owing to the high level of the subsoil water, and it is as easy to make the experiment now as to make it decades hence when other well-drained districts will be using with benefit properly constructed pit latrines unsuited to the rice flats. The African is doubtless suspicious of change, but once he is convinced that the change/

change has been beneficial his capacity for enthusiasm is boundless and often embarrassing. He is more likely to appreciate the scheme as an agricultural method involving the increased yield of his rice crops than as a sanitary measure which demands a complicated knowledge of medical science which he does not possess.

For the bulk of the population the use of boots and shoes as a method of preventing human infestation cannot be considered on the score of price. Wages are at the rate of five and six shillings a month for a labourer employed by a European, and, amongst themselves, the North Nyasa natives will accept four shillings. Canvas shoes are no use, as Hookworm larvae penetrate them when wet, and larvae can even migrate freely over the surface of wet leather boots.(40)

The question of increasing the consumption of ox meat is one that must be considered as a method of enhancing the resistance of the population to the anaemia producing properties of Hookworm infestation. This is all the more urgent as the Government is actively taking up the question of stock improvement. There were no dipping tanks in North Nyasa until 1930-1931, when no less than nineteen were built with a view to combating the tick borne protozoal fevers of cattle. The modern method of inoculating against rinderpest has already caused a great increase in the number of cattle in the district, with the consequent evil of over grazing in the dry season, and, when the benefits of dipping accrue in a few years, over grazing will/

will be still more acute all over the district in tsetse fly free areas. I consider that it would pay the Government in the long run to go to the expense of subsidising a meat industry with provision for slaughter-houses and meat markets for the sale of fresh meat, and a dried meat or compressed meat factory. Some such scheme is bound to come, and it will be necessary to see that the importance of local consumption of meat is not disregarded in favour of the purely commercial idea of exporting dried meat. The African loves meat and should easily develop the habit. By this means the health of the population would benefit, and over-grazing, with its attendant evils of stock degeneration and soil erosion, would disappear.

It will appear, therefore, that the only method of the control of Hookworm infestation available at the moment is mass treatment. In the haemoglobin value of the blood we have now an easily determined guide to the degree of infestation in the population, and by examining one hundred women yearly the position can be gauged and treatment instituted when the value falls below 70 per cent. This yearly examination will take only a day and should prove itself well worth the trouble.

To determine without doubt the value of a single campaign before going on leave in October, 1931, I started a second campaign to cover the same people. This should eliminate Hookworm infestation as a cause of haemoglobin loss for all practical purposes, and should make it possible with a little work to estimate what the loss from malaria is.

VII. CONCLUSION.

In conclusion I am sure this simple method of haemoglobin examination will prove of equal value in other districts where clinical disease is common, or at least not infrequent. All that will be necessary will be to pick a hundred adults, examine their haemoglobin, treat them, and a few months later re-examine the blood. The improvement will be a measure of the degree of infestation, and the necessity or otherwise of a mass treatment campaign will be evident. Thus, without expense and with but three days' work, the district medical officer will be able to gain a definite opinion of the degree of Hookworm infestation in his district, and by mass treatment bring health to thousands. There is no need to wait on detailed investigations; mass treatment is of proved value, and, if the population is suffering, our duty is to use it, and so banish Hookworm disease from our African dependencies.

SUMMARY.

(1) The scope of this thesis is outlined.

(2) A short historical summary of Hookworm Disease is given.

(3) A consideration of the physiographical, climatic, soil and vegetation conditions show the Karonga area to be well suited to the spread of Hookworm infestation in the wet season and for a period thereafter depending on local conditions.

(4) The particular importance of drainage as against mere rainfall is brought out by a comparison with other districts in Nyasaland, and by the increase of the disease in Karonga in recent years. Drainage in the lake shore plain is shown to be dependent on the peculiar geological formation of the area combined with equally unusual meteorological conditions.

(5) The dry season is shown to be an adverse factor of great importance to the spread of the infestation.

(6) The habits of the population produce a maximum of soil pollution, and, coupled with the vegetation and soil moisture conditions of the first six weeks of the rains, these habits make this time the most important period of the spread of the infestation.

(7) The complete failure of pit latrines to combat the spread of/

of Hookworm infestation is shown. This is due to faulty construction, improper use, and the unsuitability of pit latrines to local conditions of drainage. The possibility of the use of such pit latrines as a factor in the spread of the infestation is noted.

(8) In the absence of better methods of examination, the use of the determination of the incidence of the infestation and the haemoglobin value of the blood is discussed.

(9) The results of an investigation in 1927 are given. These prove the existence of moderately severe infestations as judged by the reduction of average haemoglobin value of the adult female population to 62.6 per cent.

(10) The best time to conduct a mass treatment campaign is discussed.

(11) A more exact examination was made of the women of three villages before treatment. After treatment, and after the ensuing wet season, a re-examination was made. The incidence of the infestation was reduced from 88 per cent to 70 per cent, and the haemoglobin rose from 62.9 per cent to 73.0 per cent, showing that, although the reinfestation rate is probably high, marked reduction in the depth of human infestation must have occurred to allow of such a rise in the haemoglobin. It follows that soil infestation must have been correspondingly/

correspondingly decreased. These figures are probably applicable to the treated, but unexamined, mass of the population, as haemoglobin readings in one village gave 73.2 per cent.

(12) The future control of Hookworm infestation in Karonga is discussed. A scheme is suggested for storing night soil for use as a fertiliser of rice. No reliance can be placed on pit latrines to prevent soil infestation. A suggestion is made to increase the consumption of meat. Complete reliance must meantime be placed on mass treatment controlled by the use of the haemoglobin value of the blood as an index of the amount of infestation present in the population.

(13) It is suggested that this method of assessing and controlling Hookworm infestation by the use of haemoglobin readings is applicable to other districts, and dispenses with the necessity of detailed examinations which occupy too much time to be serviceable to a district medical officer. Using such a simple scheme, Hookworm Disease would soon disappear.

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APPENDIX I.

The Details of a Mass Treatment Campaign.

On my return from leave in 1929 I was asked to consider the possibilities of a Hookworm campaign in the North Nyasa district, without, however, any financial aid or increase of staff, but only a guarantee of plentiful supplies of carbon tetrachloride and magnesium sulphate.

To carry out such a campaign a considerable amount of preparatory propaganda is necessary to enlist the sympathy and co-operation of the people. As the African has his own system of medicine with his own doctors, even resistance must be overcome before the people are willing to give the method a trial. However, I was in the position of having done my previous tour in the district, during which I had time to learn the ways of the people and to gain a degree of their confidence.

Regarding native ideas of Hookworm disease, there is a name "Lipasa" for the advanced stage of the disease when the patient is profoundly anaemic and his appearance characteristic from oedema and weakness. This clinical picture may also be produced by malarial cachexia, which is a frequent source of error in diagnosis even amongst European doctors. The African ascribes this condition to contact with either parent of twin children, twins being regarded by almost all Africans as a serious calamity. An old native doctor, Kasote, who was famed

for/

for his treatment of this disease, and who is now a convert to "my" theory of its causation, used to give his patients good strong purgatives with some success. Unfortunately, however, he had no method of standardising the dose of his preparation and he could never tell just how strong his purge would be, so that accidents happened. Hookworm Dermatitis of the feet or "Ground Itch" is known under the name "Fitope," and here they do approach nearer to the Hookworm theory as they ascribe this condition to the constant contact with mud in the wet season.

As these people cannot read, the method I adopted was to give talks in the villages on:-

A. The Life History of the Hookworm. This was made very simple and the points illustrated by demonstrations of ova in the stools and adult worm specimens including Ascaris, which were more effective than the smaller Hookworms.

B. The Symptoms and Signs of the Disease. As the Hookworm is unknown among the people and the disease has no outward manifestations until marked oedema is present, natives tend not to worry about the subjective symptoms, and in 1927, 1928, with a view to increasing the number of early cases attending hospital, I described the symptoms and signs of the disease in every village I stopped in. I detailed them as follows:-

(1) Epigastric pain with dyspepsia and variability of the appetite.

(2) Geophagy, especially in children.

(3) Irregularity of the bowels.

(4) Weakness and lassitude.

(5) Palpitation.

(6) Breathlessness.

(7) Vertigo.

(8) Loss of sexual vigour. This is most important to the African whose life is bound up in his progeny and whose sexual powers in health are remarkable according to our standards.

(9) Anaemia.

(10) Oedema. Especially the puffiness of the eyelids on rising in the morning.

The demonstrations of anaemia were, I think, the most effective, as I was able to pick out from the audiences probable cases of anaemia as shown by pallor of the finger nails and conjunctivae of the lower eyelid. (See Appendix II). I compared these cases with anaemia free individuals, and by examination was able to demonstrate ova, and by treatment, to leave behind people whose health rapidly improved.

These measures resulted in greater numbers of people coming to hospital with a ready made diagnosis based on some of the above symptoms, and my work of introducing the question of mass treatment was thus made easier in 1930.

The native medical staff was instructed in Hookworm talks/

talks and sent out to continue the work of propaganda. The aid of the Mission teachers was enlisted to give publicity to the scheme.

When the time came to conduct the campaign the villagers were, if not enthusiastic, at least interested in the novelty of the scheme and as treatment was given in public, usually under the shade of a big tree in the village, the contagious and often-times humorous effect of seeing others accept the dose operated on the timid and reluctant. The co-operation of chiefs, elders of the village and educated natives in being the first to accept treatment in the villages was gratifying. I started the campaign in the village of the one time fashionable native doctor of the disease, and as he was the first man to take the dose these two facts were in themselves excellent propaganda. I have much reason to thank Kasote.

The following is an extract from a description of the campaign which was officially requested by the Director of Medical and Sanitary Services for publication under the title "Notes on a Small Hookworm Campaign in North Nyasa" in the Annual Medical Report for 1930.

"A small Hookworm campaign was carried out in the North Nyasa District during September, October and November.

The District Commissioner kindly lent a Court Messenger in uniform, who, working ahead of the treatment unit, informed the headman and villagers of the date of the expected arrival of the unit at the village, and read out to them the following instructions:-

1. The day before treatment all must take a light evening meal.

2. On the morning of treatment no food must be taken.

3. There must be no beer drinking for three days before and after treatment, by those wishing to be treated.

4. No heavy drinkers were to take the treatment; if they did so the responsibility was their own, but if any such people were anxious to be treated they should consult the Medical Officer first.

The treatment unit consisted of:-

1. A well-trained dresser who had the confidence of the villagers.

2. One infectious diseases investigator who acted as an assistant.

3. One assistant who carried the drugs and mixed the Epsom salts.

I started the campaign personally during the first week and we usually arrived at the village at about eight in the morning, the time depending upon the distance to be travelled. We then proceeded to give the doses of carbon tetrachloride to the assembled people. After this an address was given upon the subject of Hookworm - the life history, symptoms of infection, and methods of combating the disease, with special reference to sanitation. When the Epsom salts were given, all were told not to go away finally until their bowels had acted. Any who had not had a motion of the bowels within an hour and a half were given another dose of salts.

On the third day after starting the treatment, I was approached by a man who was known to be a heavy beer drinker and who admitted it himself. From his appearance this was obvious. He was told that he could be treated if after having a dose of calomel and salts, he took no beer for a week. A week later he appeared at another village and asked for treatment and said that he had, as instructed, been without beer for a week. He was then given the treatment, and in the afternoon of the same day he was attacked with a violent pain over the liver and epigastrium, accompanied with severe vomiting, eventually, according to report, of blood. He was brought to the hospital on the next day in a drowsy, apathetic condition, with well-marked jaundice. His urine contained a trace of albumin, his bowels were confined, and his/

his liver was tender, but there was no rigidity of the abdomen. There were no signs of paralysis. He could only be roused with difficulty and his speech was slow and thick with marked tremor of the lips and tongue.

The stupor soon became coma, and his condition became that of the "wet brain" type of alcoholism with the addition of jaundice.

In spite of all treatment he died on the third day. (A post-mortem was refused).

Further enquiries showed that he had continued beer drinking after the warning, and was actually, the night before his treatment, "dead drunk," but having gone to another village for his treatment there was nobody there who could know about it.

Thinking that this unfortunate occurrence would jeopardize the campaign, the advantage was taken at a Chiefs' meeting at the Boma a few days later, to explain matters. The Chiefs were, however, quite satisfied that, in the words of one of them, - Kasote again - "his own foolishness killed him."

The campaign proceeded without a hitch thereafter, the people being greatly impressed by the quantities of round worms and tapeworms voided after treatment, the hookworms being too small for much consideration. Numerous people came from villages further afield asking for treatment and the whole campaign was very popular.

The doses of carbon tetrachloride given were 60 minims as a maximum for well-built men; women received rather less, whilst children were given 3 minims for each year of age. A total of 4,461 people were treated.

Regarding the death described above, I became aware of the bad effect of beer drinking when combined with carbon tetrachloride some three years ago when a dispenser reported the death of a man, who, after taking a dose of carbon tetrachloride, followed it with a beer drink. Subsequently I had seen two cases of severe epigastric pain and vomiting with tenderness over the liver and jaundice, where beer drinking was associated with carbon tetrachloride. These cases recovered however.

It was on account of these cases that the stipulation about beer drinking was made in the instructions to the villagers."

The poisonous action of carbon tetrachloride is on the liver,[1] and it is not quite such a safe drug as was thought when it was first introduced. From the literature on the subject I find that predisposing causes of poisoning in addition to alcoholism are:-[2]

(1) The presence of Ascaris in the bowel.[3]

(2) The presence of undigested food, especially fat, in the intestine.

(3) The existence of calcium deficiency in children.

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APPENDIX II.

A Note on the Clinical Diagnosis of Hookworm Disease, with special reference to an Early and a Late Sign.

In my introduction to this thesis, I mentioned that Hookworm infestation was a cause of lowered resistance,(1) and I have noticed this fact most often in the treatment of ulcers, one of the commonest conditions of Tropical Africa. Ulcers in very many cases refuse to heal until the underlying complaint of Hookworm disease is treated.(2) I would even go so far as to say that this disease stands on a par with Malaria and Syphilis as factors which militate against proper healing.

It is therefore essential in a busy hospital with a large dispensary practice in a Hookworm infested district to be on the alert for this disease. Not only at the hospital is this necessary, but in the district also much useful work can be done by diagnosing and treating Hookworm infested people who are ignorant of the disease and who live too far away to attend the hospital. I wish, therefore, to describe an early, easily observed sign of the Anaemia of the disease which is particularly noticeable in the African and which is of the greatest help in drawing one's attention immediately to the possible presence of the disease.

When anyone is suffering from anaemia, pallor of the finger nails is present, but in the white-skinned races it is not very noticeable. In the African, however, pallor of the finger/

finger nails is very noticeable as it is brought into excellent relief by the contrast of the surrounding black skin. Again, the African gesticulates freely with his hands and so it happens that with the customary appraising look at the appearance of a patient this tell-tale pallor, if present, is observed. When I note it, without interrupting the usual conversation between doctor and patient, I depress the lower eyelid, and finding confirmation of the existence of anaemia, proceed to determine its cause, irrespective of the nature of the patient's complaint which may be trivial and not suggestive of Hookworm Disease.

When the sign is present in children and adolescents the diagnosis of the cause rests between Hookworm Disease and Malaria with, of course, the possibility of both conditions co-existing. If the spleen is not palpable, then Hookworm Disease is the probable cause, and, if I am on trek, no further examination is made and the patient is treated. In hospital it is possible to determine the cause more exactly by stool and blood examination, but unfortunately even here the only treatment which is effective is the one for Hookworm Disease, as parents seldom bring their children back to hospital for another supply of quinine when the diagnosis involves Malaria.

In adults with anaemia first observed by this pallor of the finger nails, the diagnosis is most likely to be Hookworm Disease, as almost all adults have reached a stage of relative immunity to Malaria, and in the absence of a palpable spleen the diagnosis can be confirmed by stool examination when the patient/

patient is seen at the hospital.

Pallor of the palms of the hands is often more easily seen than pallor of the finger nails, but I would not rank it as a definite sign, as it is more open to fallacy. In men and women whose palmar skin is greatly thickened by hard work with the hoe or axe a pallor of a yellowish colour is present due to the fact that one is looking at a layer of skin which is too thick to allow the colour of the blood to shine through. However when the skin is of normal thickness this sign is useful as it attracts notice.

There is another easily observed sign of Hookworm Disease in the young and to a less extent in adults of the Bantu race. Unfortunately it is present only in the advanced stages of the disease when the anaemia is marked and the patient ill and weak. It is remarkable, however, how seldom parents recognise serious ill-health in their children, and I have "spotted" many cases of the disease from this sign. It consists of a loss of pigment in the hair coupled with a loss of tone which makes the hair mousy brown in colour, finer in appearance, not so crisp to the touch and almost silky when felt in well-marked cases. It is a most striking condition in comparison with the usual crisp, black, curly condition of the hair normally in the African, and it reminded me at once of the similar condition found in Europeans suffering from Tuberculosis. As Tuberculosis is extremely rare in North Nyasa I am unable to throw any light upon what effect, if any, this disease may have on the hair of the African. As in Tuberculosis, there is also a tendency for the spread of the/

the growth of fine hair onto the forehead and cheeks and along the spine.

This sign is also found in African children and adolescents suffering from Malarial Cachexia and one must remember to differentiate the two conditions.

The only reference I have seen to any change in the condition of the hair in Hookworm Disease is a note by Spear who observed that in sufferers from this disease in Cuba the hair lacked lustre and looked dry.(3)

These hair changes are often associated with a degree of Infantilism in the patient and Osler under Cachectic Infantilism lists Hookworm, Syphilis and Malaria as the causes of this type.(4) There is a possibility that this may be associated with endocrine gland disturbance, and Simonin states that endocrine glandular insufficiency results from the toxic cellular degeneration of liver, pancreas and suprarenals in intestinal Helminth infestations.(5)

It may be of interest to explain the manner in which my attention was first drawn to this pallor of the finger nails.

When I went out to Nyasaland I was stationed in Zomba, where, among other duties, I held that of medical officer to the central prison of the country. Every Monday morning I made a complete survey of the prison and prisoners along with the superintendent. The prisoners were drawn up in lines in the prison yard and on the word of command the members of each line took off their clothes. As I moved down the line, each prisoner, when I came abreast/

abreast of him, raised his hands to half shoulder level, palms downward, then palms upward. This was for the purpose of facilitating the examination for possible scabies, and, becoming accustomed to this rapid examination of appearance, I soon noted differences in the colour of the finger nails and palms of the hands. It was not until I went to Karonga that the true significance of such changes dawned on me, as in Zomba central prison all prisoners are examined for helminthic infestations on admission and treated if necessary, so that marked anaemia was rarely seen. In Karonga, on the other hand, Hookworm disease is common and I soon noted the correlation of the disease with evidences of anaemia as shown by the pallor of the finger nails and palms of the hand.

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